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FURTHER STUDIES IN THE RESPIRATION OF SUGARCANE *IN SITU*

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(Received for Publication on 29 January 1947)

(With one text figure)

In the previous paper the authors [1938] has described the effect of increasing drought on the rate of respiration of different varieties of sugarcane. The periodic fluctuations were observed to be more consistant in some of the varieties than in others. The results further indicated, that with passage of time and possibly through adoptation the two-hourly fluctuations in the respiratory activity of varieties narrowed down considerably later in the season. Field observations on the growth of crop under the unirrigated conditions of North Bihar plainly pointed to the fact, that critical hot, weather very much determined the growth and final yield of the different varieties at harvest. Further it was noticed that different periods during this critical stage mainfested a different effect on the various varieties. In order to elucidate these facts, further experiments were conducted on varieties Co213(St.), Co299, Co313, Co331, Co356, Co419 and Co421. Respiration studies on variety Co213, as the standard variety, were conducted on all the days of the experiment to compare its results with those of other varieties under tests.

Experimental procedure

The same apparatus as described by the authors for the previous investigations was brought into use. Of the above mentioned seven varieties, five were the same as in the previous study. The physiological experiment was so planted in a uniform field that every alternate plot had variety Co213. The experimental plants were labelled after selection before the experiments commenced. An equal number corresponding to those of the varieties were selected and labelled for Co213. Two apparatuses were run simultaneously. One of them was exclusively used for Co213 which served as control for every determination made for other varieties. The rate of respiration reported is in c.c's. carbon dioxide per gramme of dry weight of the substance.

Experimental results

The respiration data on variety Co213 throughout the season for the different periods are given in Table I and graphed in fig. I of the text. This represents the respiration rate during the period 7-30 a.m. to 9-30 a.m. when the atmospheric conditions were more normal. The variations in temperature have also been graphed in the figure to illustrate, that the temperature variations during this period were seldom abnormal except in the last period of determination when they showed greater fluctuations day after day from the mean of about 33°C. So that, the rate of respiration between these hours may be taken, as consistent for all these days, the variations being attributed to the variations in the inherent ability of the selected plants to metabolise. A free hand curve thus drawn out with the available data through some of the points, indicated four distinct types combined into one which corresponded more or less to each of the four periods of study. In the first period a steep fall in the curve was noticed. In the second period some rise was indicated, the maxima of the curve being reached about the end of second and the beginning of the third period. This was followed by a gradual decline in the curve. The fall in the curve during the fourth period was more steady and long delayed than in the third period.

Kidd, West and Briggs [1921] observed that the respiratory index of the meristematic tissues decreased with age. The fall was noticed to be very pronounced after the first thirty days. Thereafter, the decrease in the rate of respiratory activity was less marked. In our studies, a regular fall in the respiratory activity was not manifested with age but in different periods the reaction of the plan to the environment in the critical weather extending over a month was different. While in the first period the rate of fall was very much pronounced, it was less so in the fourth period. In the

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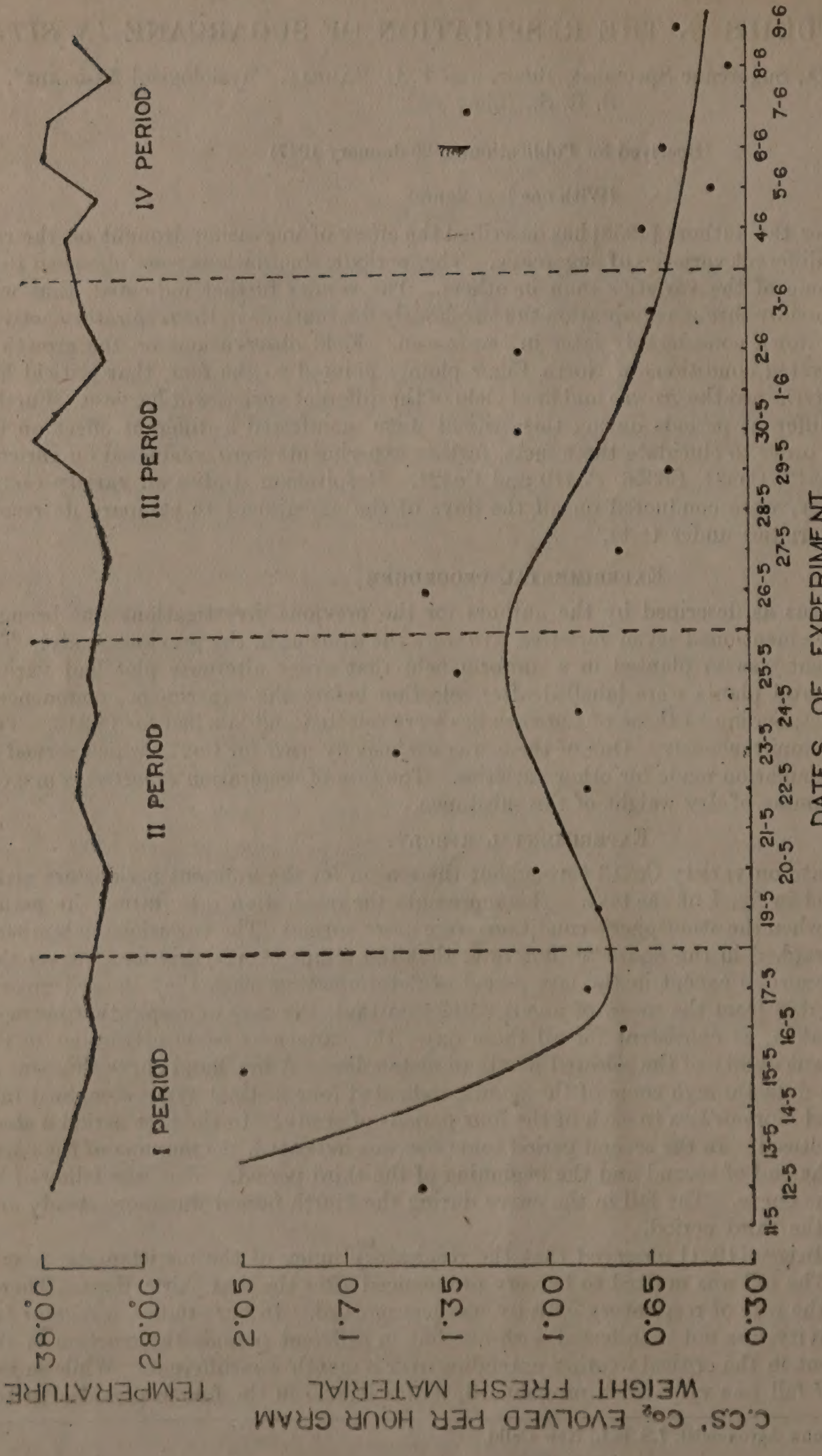

FIG. 1. RESPIRATION STUDIES ON Co. 213—7·30—9·30 A.M.

intervening period however, a rise in the respiratory activity was exhibited. Thus in *situ* studies the respiratory behaviour of meristematic tissues was altered by the environment.

As stated already, five of the varieties under the experiment were the same as in the previous experiment. Thus, an opportunity was availed to compare their behaviour critically. The complete data for the two seasons are reported in Table II, and their analysis is given in Table III.

Table I

Comparative respiratory activity of varieties in Situ

Nature of trial	Name of variety	Time intervals during the day: 7-30—9-30 a.m. A	7-30—9-30 a.m. B	9-30—11-30 a.m. A	9-30—11-30 a.m. B	11-30—2-0 p.m. A	11-30—2-0 p.m. B	2-0—4-0 p.m. A	2-0—4-0 p.m. B
		First Period							
		C.C.'S	0°C	C.C.'S	0°C	C.C.'S	0°C	C.C.'S	0°C
Early varieties .	Co299	1·36	35	1·18	40	1·61	43	1·86	43
	Co213	1·11	35	1·27	40	1·11	43	2·05	40
	Co313	0·27	31	0·41	35	0·54	37	0·88	38
	Co213	1·45	31	0·17	37	1·18	38	1·02	35
Mid-season varieties	Co356	1·49	31	1·63	36	0·90	42	0·89	37
	Co213	..	..	..	..	..	..	..	..
	Co419	0·94	30	1·10	37	0·67	42	0·78	40
	Co213	0·86	30	0·89	37	0·69	44	0·89	42
Late varieties .	Co331	0·90	28	0·97	37	0·77	45	0·78	38
	Co213	0·74	30	0·96	37	0·66	45	0·42	38
	Co421	0·84	30	0·58	35	0·34	40	0·94	35
	Co213	2·21	30	2·19	35	1·44	40	0·96	35
		Second period							
Early varieties .	Co299	0·86	31	0·89	34	0·94	40	0·69	40
	Co213	0·82	31	0·74	34	0·55	43	0·79	40
	Co313	0·45	29	0·88	35	0·67	43	0·73	40
	Co213	1·03	30	0·93	35	0·87	44	0·66	40
Mid-season varieties	Co356	0·99	29	0·94	39	0·86	44	0·44	42
	Co213	0·86	30	0·83	40	1·14	47	0·74	44
	Co419	1·09	29	0·54	37	0·76	42	0·84	37
	Co213	1·30	29	0·36	37	0·71	44	0·87	37
Late varieties .	Co331	0·79	27	1·20	37	0·87	44	0·91	44
	Co213	1·50	29	1·12	39	0·88	47	0·74	44
	Co421	0·76	30	0·84	35	0·78	40	0·78	35
	Co213	0·89	30	1·09	35	0·94	38	0·99	35
		Third period							
Early varieties .	Co299	0·75	27	1·13	36	0·47	42	0·77	36
	Co213	1·40	27	1·18	38	0·86	43	1·21	36
	Co313	0·63	26	0·67	36	0·75	40	0·73	40
	Co213	0·74	26	0·83	40	0·83	45	0·59	40
Mid-season varieties	Co356	0·98	40	1·06	43	0·86	47	1·07	45
	Co213	1·08	40	1·30	43	0·78	48	0·73	45
	Co419	1·02	28	0·74	38	0·80	43	1·03	38
	Co213	0·62	28	0·59	38	0·43	45	0·45	38
Late varieties .	Co331	1·08	27	0·85	35	0·69	43	0·69	40
	Co213	1·08	27	0·85	35	0·78	47	0·66	43
	Co421	0·60	26	0·82	39	0·68	45	0·72	40
	Co213	0·57	28	0·82	39	0·60	48	0·70	40

TABLE I—*contd.*

Comparative respiratory activity of varieties in situ—contd.

Nature of trial	Name of variety	7-30—9-30 a. m. A	7-30—9-30 a. m. B	9-30—11-30 a. m. A	9-30—11-30 a. m. B	11-30—2-0 p.m. A	11-30—2-0 p.m. B	2-0—4-0 p.m. A	2-0—4-0 p.m. B
				Fourth period					
Early varieties	Co299	0·88	32	1·04	38	1·61	43	0·70	37
	Co213	0·65	32	0·84	38	0·92	43	0·58	37
	Co313	0·60	30	0·74	35	0·65	40	0·42	35
	Co213	0·41	30	0·45	35	0·44	40	0·43	35
Mid-season varieties	Co356	0·43	27	0·47	32	0·41	32	0·43	30
	Co213	0·35	29	0·46	32	0·32	30	0·41	30
	Co419	0·57	29	0·77	33	0·60	40	0·87	40
	Co213	0·53	29	0·46	40	0·21	44	0·68	40
Late varieties	Co421	0·75	30	0·91	39	0·38	42	0·54	39
	Co213	1·27	33	0·67	42	0·49	42	0·49	39
	Co331	0·44	33	0·72	40	0·68	43	0·52	40
	Co213	1·25	33	0·91	43	0·51	45	0·34	40

NOTE.—A=Rate of respiration in c.c.'s B=Temperature °C

TABLE II

Preliminary analysis of the respiration data for the two seasons

Periods of study	I—Seasons Co299	Co313	Co213	Co356	Co331	II—Seasons Co299	Co313	Co213	Co356	Co331
I	2·92	2·79	7·79	4·29	3·25	6·01	2·10	4·82	4·91	3·42
II	2·80	3·12	2·85	3·76	3·22	3·38	2·73	3·49	3·23	3·77
III	3·37	2·09	1·97	3·84	2·63	3·12	2·80	2·98	3·97	3·18
IV	3·13	2·41	2·20	2·25	2·61	4·21	2·41	1·73	1·74	2·36
Total	12·22	10·41	14·81	14·14	11·61	16·72	10·04	13·02	13·85	22·73

Time intervals	I—Season Co299	Co313	Co213	Co356	Co331	II—Season Co299	Co313	Co213	Co356	Co331
8-30—9-30 a.m.	2·54	2·52	3·26	3·27	2·48	3·85	1·95	3·63	3·89	3·18
9-30—11-30 a.m.	4·46	2·96	4·20	4·14	3·23	4·42	2·72	3·38	4·10	3·74
11-30—2-0 p.m.	2·74	2·62	4·41	3·24	2·92	4·63	2·62	3·31	3·03	3·01
2-0—4-0 p.m.	2·28	2·31	2·94	3·49	2·98	4·02	2·76	2·70	2·83	2·80

TABLE III

Analysis of Variance Respiratory activity of the varieties in the two seasons

Due to	Degrees of freedom	Sum of squares	Mean variance	Value of F Observed P=5 per cent	Value of F Theoretical P=1 per cent
Seasons	1	0·06	0·060	1·09	3·92
Varieties	4	1·54	0·385	7·00	3·47
Periods	3	3·90	1·300	23·63	3·94
Time intervals	3	0·92	0·307	5·58	3·94
Seasons x varieties	4	0·72	0·180	3·27	2·44
Seasons x periods	3	0·07	0·023	0·0042	..
Seasons x time intervals	3	0·21	0·07	1·27	..
Varieties x periods	12	4·57	0·381	6·93	2·33
Varieties x time intervals	12	0·43	0·036	0·0065	..
Error	114	6·27	0·055	..	..
Total	159	..	..	..	..

It is evident that the gross effect of seasons did not indicate a wide significant difference in the respiratory activity of the varieties. But the differences amongst the respiratory activity of the varieties were significant for the mean values of the two years. Thus, critically, the respiratory activity values were the same for Co213, Co356 and Co299. But then all these had significantly higher rate of respiration of the plant material than Co313, Variety Co299, however, alone had significantly higher rate of respiration than Co331. This was irrespective of the seasons, time intervals and the periods of working.

Significant differences amongst the periods were also observed. Mean values for the two seasons indicated the position as under :

Period I, Period II, Period III and Period IV

The respiratory activity was cut down in the second period by about 0·25 c.c. and this difference was observed to be significant. The difference between the second and the third periods was small and not significant that is 0·06 c.c. only. Between the third and the fourth periods the difference was again wide, the decrease being as much as 0·12 c.c. and this difference was critically significant. Thus irrespective of the varieties, the seasons and the time intervals, it is observed that the respiratory activity of the plant material decreased as time elapsed. Thus our results in this instance confirm the findings of Kidd, West and Briggs reported earlier.

The interaction between the varieties and the periods was also observed to be significant. The mean data are reported in Table IV as under :

TABLE IV

Interaction effect between the varieties and the periods

Varieties	Periods of working I	II	III	IV
Co299	1·116	0·772	0·811	0·917
Co313	0·611	0·731	0·611	0·603
Co213	1·578	0·793	0·619	0·491
Co356	1·150	0·874	0·976	0·499
Co331	0·821	0·873	0·726	0·621

S.E.= ± 0·2345 C.D. at 5 per cent level= ± 0·2323

Except the variety Co313 all others exhibited significant differences amongst the various periods. Variety Co213 indicated the maximum depression. While the varieties Co213, Co356 and Co299 had the highest rate of respiratory activity in the first period, Co331 had the highest activity in the second period. The respiration of all these varieties was significantly higher in the second period as compared to the fourth period. The third and the fourth periods in all, except Co356, did not show significant differences amongst the respiratory activity of the plants. In the current season Co421 behaved identical to Co299 and the behaviour of Co419 was similar to Co313 and Co331. All these observations indicate that varieties respond differently at various periods in the general enssemble of the environment. But perusal of the data given in Table IV above clearly indicate and confirm the fact, that, drought susceptible varieties such as Co213 and Co356 cut down their respiration rate more rapidly than Co313 or Co331. Variety Co313 tended to maintain its respiration rate to the original level in the fourth period of investigation.

Further on, it was observed that, varieties in the two seasons responded differently to the environment as given in Table V :

TABLE V

Interaction effect between the varieties and the seasons

	Varieties				
Seasons	Co299	Co313	Co213	Co356	Co331
I	0·751	3·651	0·926	0·884	0·726
II	1·046	0·628	0·814	0·866	0·796

S.E.= ± 0·2345 C.D. at 5 per cent=00·164

Thus Co313, Co213 and Co356 had higher rate of respiration in the first season than in the second. And on the contrary Co299 and Co356 had higher rate in the second season than in the first. It is only in the case of Co299 that the difference was highly significant.

SUMMARY

Respiration studies on seven varieties of sugar cane were carried out during the hot weather to see how far confirmatory evidence is available for conclusions drawn in the previous paper and also study how for differences in the seasons and the periods of study influence the results. These results are summarized as under :

1. During the day the two-hourly fluctuations in the course of respiration are regulated by the variations in the temperature factor which caused significant differences in the rate of respiration of the plants.

2. The respiration record on plants of variety Co213 was taken on all the days during the four periods. In the first period a steep fall in the course was noticed. In the second some rise was indicated, the maxima being reached in the end of second and about the beginning of the third period of study. Later the respiration curve declined gradually.

3. Analysis of variance of the data of five varieties studies in the two seasons, indicated firstly a significant difference amongst the varieties irrespective of the time intervals, seasons and periods of study. Secondly, the varieties behaved somewhat differently in the two seasons. Thirdly, the varieties exhibited different rate of respiration in the various periods. In general, varieties Co213 and Co356, cut down their respiratory activity more rapidly than Co313 or Co331.

4. Combined data for the two seasons, confirmed the observation. that under drought resistant conditions the rate of respiration decreased with the passage of time. The drought susceptibles cut down more rapidly their respiratory activity than the less drought resistant ones.

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RESPIRATION STUDIES IN SUGARCANE UNDER PARTIAL SUBMERGENCE

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(Received for publication on 13 May 1947)

(With three text figures)

MAJOR portion of the precipitation in North Bihar is received during the monsoon period. Whenever there occurs a continuous spell of rain, large masses of water are released into, the rivers which come in spate and inundate extensive areas year after year. Lowlying fields adjacent to the rivers are specially thus inundated. Since no other crop can withstand stagnation of water, such lands are usually cropped with sugarcane. Silt deposited by the flood water enriches the land. The crop though receiving a setback by water stagnation otherwise improves in growth because of improved fertility of the land. The problem of partial submergence of sugarcane, therefore, is an important one both from the scientific and the economic point of view.

THE MATERIAL AND METHODS

Preliminary observations on various crops showed that under conditions of partial submergence maize crop was the one worst affected, while sugarcane withstood the stagnation of water for a considerable period. Therefore a preliminary study, in the first instance, was made to compare the effect of partial submergence on maize and sugarcane simultaneously. For the purpose the rate of respiration of maize and sugarcane or leaves of normal crop and of submerged crops after one and two days of partial submergence was studied. On the first day of submergence the depth of water was 1½ ft. and on the second day when the samples were drawn the level of water was about 3 ft. in depth. The results of these preliminary observations gave a ground for further studies. A number of varieties differing considerably in their tolerance to partial submergence were taken up for respiration studies. Plant material was drawn both from the high land (unsubmerged) and the low land (partially submerged crop). The plants of the same variety were removed from their natural habitats at one and the same time. The studies on all the eleven varieties were completed within three days, that is, five to eight days after partial submergence. The depth of partial submergence was 1½ ft. while the crop had a general height of over 3½ ft. The plants for both these studies were dug out with a ball of earth one cubic foot in volume. Roots were thoroughly washed and cleaned of all vegetable matter before their respiration was studied. Laminae separated from the sheaths were used for study of respiration. Canes were cut into pieces of the size of 1½ ft. each, before they were put in the respiration chamber. The varieties studied were Co. 281, Co. 300, Co. 313, Co. 318 Co. 320, Co. 326, Co. 331, Co. 345, Co. 346, Co. 290 and Co. 285 the material for which was available under identical conditions on the high and the low land. Material in each case was kept for respiration studies for three hours. The results obtained were suggestive enough to confirm them under a set of controlled conditions.

For controlled experiments, the study was restricted to varieties Co. 210, Co. 213, Co. 281, Co. 285, Co. 313, and Co. 326. Of these, varieties Co. 210, Co. 213, and Co. 313 are the standard varieties of the tract. Variety Co. 281 is an early variety susceptible to the effect of partial submergence. Rest of the varieties possess high field resistance to the effect of partial submergence. Five clumps of each of these varieties were dug out with a ball of earth round each of the clumps. The ball of earth, in every case, was two feet in diameter and 1½ ft. in column which was tied all round with gunny to save the ball from crumbling when placed in water. Out of the five clumps, four were placed in water supported on bamboo support specially erected for the purpose. The fifth in every case was immediately dissected for studying the respiration rate of leaves, cane stalks and roots. Out of the four clumps, each one was taken out at the proper time. While its leaves and canes were

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immediately put in the respiration chambers, roots in the meanwhile were washed and cleaned. One by one these clumps were taken out after 24 hours (one day), 72 hours (3 days), 120 hours (five days), and 168 hours (7 days) respectively.

In the following year, an opportunity under natural conditions, presented itself to compare the respiratory behaviour of Co. 213 plant and Co. 213 ratoon crops. It was possible to follow up the course of respiration of the foliage for about a fortnight. The low land area was the old bed of the river and when once inundated it maintained the same level of water as the river in spate. During the first seven days there was a constant rise of water but when examined on the last day it was found that the crops in both the cases were completely submerged under water for a day. Then the water started receding and the fall continued up to the tenth day. Later on, it again began to rise and after two days rise, it was almost stationary for the next two days. After a fortnight the studies were discontinued. In this case seven standard leaves (transverse mark) were taken from each of the crops and their rate of respiration was determined.

Method of gaseous exchange for the study of respiration of plant material was used throughout the period of experiment. The essential details of the apparatus were the same as used by Luthra and Chima [1937]. The air, however, before entering the respiration chamber was freed of water vapour by passing it through a bottle containing concentrated sulphuric acid. Instead of sodium hydroxide solution a measured amount of bryta solution was used to absorb the carbon dioxide evolved by the respiring material. The bryta solution in the last U-tube itself served as a test that the air was free of carbon dioxide. Throughout the period of the experimentation the temperature was maintained at 30°C. which was the usual temperature prevailing in the laboratory during the monsoon period. The rate of respiration was calculated per hour per gramme on the basis of the fresh weight of the material.

Experimental results

Maize is one of the plants which is sensitive to scarcity of oxygen supply. In order to compare the response of partial submergence in the comparative rate of respiration of cane and maize leaves, standard leaves were taken from seven of the plants in both cases and subjected to experimentation on different dates. The following Table (Table I) is a brief summary of the results with maize and sugarcane growing side by side under identical conditions of partial submergence of flood water :

Table I

Rate of respiration under normal and submergence conditions

Date of study	Degree of submergence	Sugarcane Co. 281	Maize Local	Remarks
30-8-35	Normal Crop . .	0·330 C.C.	0·430	The crops were growing in the old bed of the river Tarani Gandak. The observations on the normal crop were recorded in anticipation of the flood
31-8-35	1½ ft.	0·285 C.C.	0·249	
1-9-35	3 ft.	0·220 C.C.	0·231	

The sensativeness of maize to scarcity of oxygen supply is evident from a very much reduced rate of respiration of leaves. The differences respectively were 0·185 C.C. and 0·045 C.C. per hour per gramme fresh weight of the material. On the second day the reduction in the respiratory activity was more in sugarcane than maize leaves, although the total reduction in maize was still greater than in Sugarcane. The leaves of maize crop exhibited tendency of physiological wilting within 24 hours of partial submergence and after 48 hours rotting had set in and plants perished shortly thereafter. After the above preliminary observations, more detailed observations were recorded on 13 varieties to compare the respiratory activity of leaves, cane and roots under normal and submerged conditions. The results derived have been summarized in Table II.

TABLE II

Comparative metabolic studies of normal (A) and partially submerged (B) material
(Rate of respiration—CO_2 evolved per hour per Gm. fresh weight of material)

Nature of material		Foliage	Cane	Roots
Group I—				
Co.331	A	0·331	0·024	0·046
	B	0·478	0·033	0·632
Co.326	A	0·216	0·043	0·249
	B	0·227	0·028	0·227
Co.318	A	0·239	0·032	0·136
	B	0·395	0·052	0·174
Co.285	A	0·329	0·048	0·248
	B	0·350	0·039	0·416
Group II—				
Co.301	A	0·280	0·026	0·123
	B	0·358	0·099	0·326
Co.320	A	0·391	0·044	0·392
	B	0·221	0·065	0·606
Co.345	A	0·290	0·046	0·057
	B	0·390	0·044	0·196
Co.346	A	0·245	0·033	0·095
	B	0·264	0·034	0·220
Group III—				
Co.313	A	0·250	0·045	0·282
	B	0·182	0·032	0·188
Co.281	A	0·720	0·053	0·391
	B	0·743	0·097	0·820
Co.210	A	0·275	0·026	0·160
	B	0·317	0·123	0·357
Co.213	A	0·271	0·045	0·222
	B	0·339	0·079	0·276
Co.300	A	0·203	0·058	0·100
	B	0·235	0·114	0·340

From the tabulated results it is evident that after five days submergence, the rate of foliage respiration in most of the varieties was higher in the partially submerged material than the normal one. Varieties Co. 313 and Co. 320 only had higher rate of respiration of the normal crop than the flood subjected ones. Most of the varieties exhibited higher respiration rate of the cane material after five days submergence, except varieties Co. 313, Co. 345 and Co. 326, which had lower rate than the normal crop. Same trend was evident in respect of rate of root respiration. Except varieties Co. 313 and Co. 326, all others exhibited higher rate of respiration for the submerged material as compared to the normally growing crop of these varieties. It will be noticed that Co. 313 showed lowered rate of respiration for foliage, cane and roots for the partially submerged crop than the normal one (figs. 1-3).

The data were statistically analysed and these results have been resummarised in Table III relating to foliage, cane and root respiration studies irrespective of the varieties :

TABLE III

Differences between the rate of respiration of Normal (A), and Partially submerged (B) material

Particulars	Foliage		Canes		Roots	
	A	B	A	B	A	B
Mean values of the rate of respiration	0·311	0·351	0·040	0·065	0·224	0·367
S. D. of the difference between two means.	±0·152			±0·0165		±0·169
Calculated value of 't' . . .		0·67		3·862		2·187
Significance by 't' test . . .	Not Significant		Significant at P-0·05		Significant at P-0·05	

Statistical analysis of the data irrespective of the varieties indicated a mean difference of 0·040 C.C. with a standard deviation of ±0·152. This difference in the rate of foliage respiration was statistically not significant in favour of the partially submerged material. It may be pointed out that the leaves taken for respiration were not in water and, therefore, not directly subjected to scarcity of oxygen. The loss of aeration in the soil on root system was indirectly exerting a physiological influence on its respiratory activity.

Most of the portion of cane and the entire root system were under submergence and thus directly affected by scarcity of oxygen supply to the tissues. The mean difference in the respiration of normal and partially submerged cane material was 0·025 C.C. The standard deviation of the difference between the two mean values was ±0·0165 C.C. and this difference was statistically significant at 5 per cent level of significance. In root respiration, the difference was 0·143 C.C. and this difference was again significant at the same level of significance.

With a view to elucidate the effect of elapsing time on the rate of respiratory activity on plant parts, controlled studies were conducted on seven important cane varieties in the manner explained already in the preceding text. The following abbreviated Table IV shows the relative effect of elapsing time on foliage, cane and root respiration of different varieties.

TABLE IV

Effect of Partial Submergence on Respiratory Activities of Different Varieties (rate of respiration in C.C. $Co._2$ evolved per hour per Gramme Fresh Weight)

Plant Organ	Period of partial submergence	Rate of Respiration in Varieties						
		Co. 313	Co. 281	Co. 210	Co. 213	Co. 331	Co. 326	Co. 285
Foliage . .	Control . .	0·24	0·23	0·15	0·14	0·19	0·34	0·37
	24 hours . .	0·45	0·19	0·23	0·32	0·15	0·26	0·32
	72 hours . .	0·27	0·20	0·38	0·25	0·20	0·32	0·36
	120 hours . .	0·23	0·16	0·42	0·35	0·23	0·36	0·45
	168 hours . .	0·12	0·12	0·38	0·31	0·24	0·39	0·38
Cane . .	Control . .	0·021	0·31	0·050	0·037	0·027	0·019	0·013
	24 hours . .	0·039	0·023	0·031	0·029	0·018	0·016	0·034
	72 hours . .	0·019	0·014	0·024	0·038	0·012	0·036	0·019
	120 hours . .	0·023	0·015	0·039	0·034	0·025	0·026	0·022
	168 hours . .	0·017	0·035	0·026	0·021	0·029	0·026	0·023
Roots . .	Control . .	0·22	0·24	0·16	0·19	0·10	0·08	0·18
	24 hours . .	0·19	0·42	0·22	0·17	0·11	0·23	0·21
	72 hours . .	0·13	0·26	0·22	0·18	0·16	0·24	0·28
	120 hours . .	0·15	0·10	0·08	0·20	0·19	0·09	0·25
	168 hours . .	0·26	0·29	0·16	0·19	0·10	0·21	0·21

The results of the studies have been graphed in Fig. 4 here. For comparative elucidation the data have been separately shown for each of the varieties and for the three types of material roots, Cane, and foliage. Of all the seven varieties Co. 285 was observed to be the least susceptible of all to prolonged effect of field partial submergence [Khanna and Venkatraman -1930]. The curve of Co. 285 foliage respiration shows that the plant to meet the abnormal environment cut short its respiration rate during the first 24 hours, after which it indicated a rise in respiration rate, which was maintained up to five days. On the seventh day of submergence, though the fall was recorded, the rate of respiration was still higher than that of the normal plant. It will be observed that varieties Co. 326 and Co. 331 also exhibited similar trends in the curves of their foliage respiration. From fifth to seventh day the rise of the curve was rather slow in spite of the fall exhibited by variety Co. 285 in its foliage respiration. The other four varieties, however, exhibited different trends in their respiratory activity with the elapse of time. For instance the respiratory behaviour of Co. 210, a susceptible variety, was altogether different from the tolerant ones such as Co. 285, Co. 331 and Co. 326. Very shortly after submergence, it started with a higher rate of respiration which successively went on increasing up to 120 hours (five days) when it tended to fall rather very slowly within the next 48 hours. In the curve of respiration of variety Co. 213 if the rate of respiration recorded on the third day be omitted and another interpolated in its place, it will be observed that the rise and fall of curve becomes identical to that of Co. 210. Similarly if an interpolation be effected in the curve of respiration of variety Co. 313 as indicated in the graph, the course of curve becomes almost identical to that of

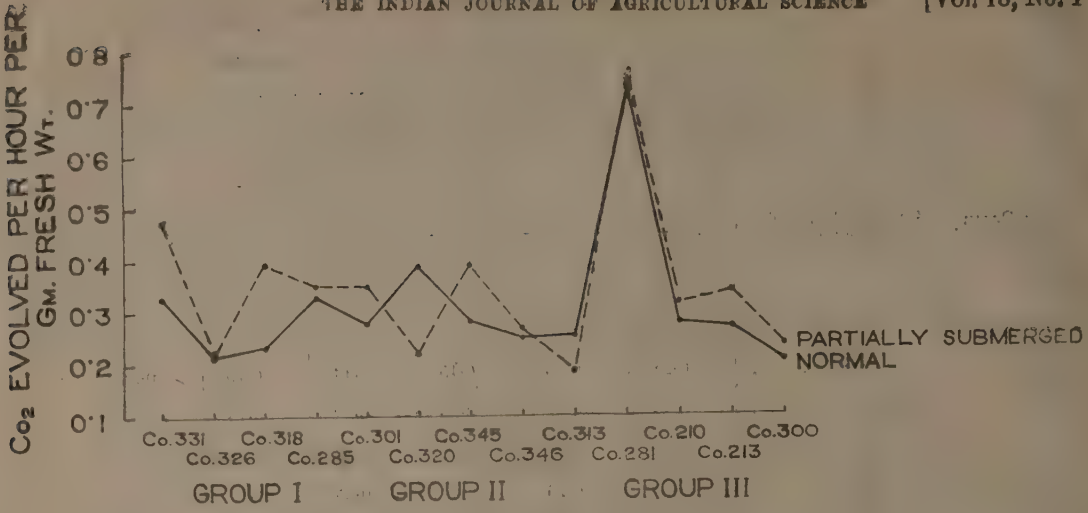

Fig. 1.
Rate of respiration of foliage

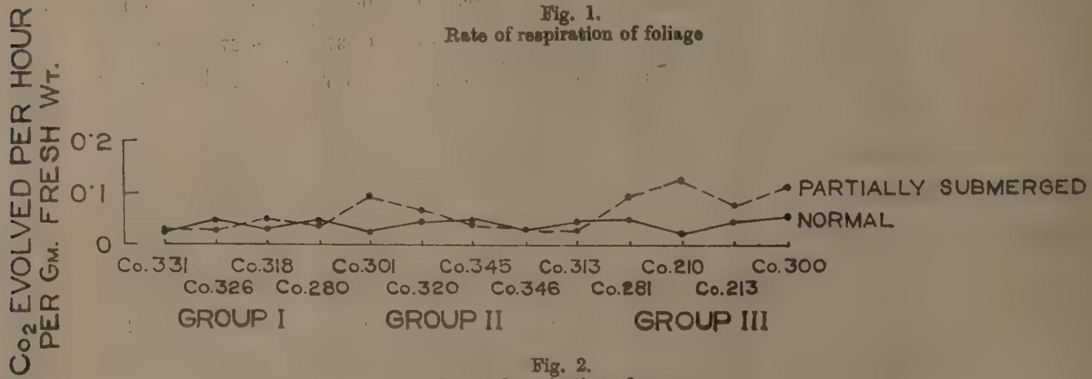

Fig. 2.
Rate of respiration of cane

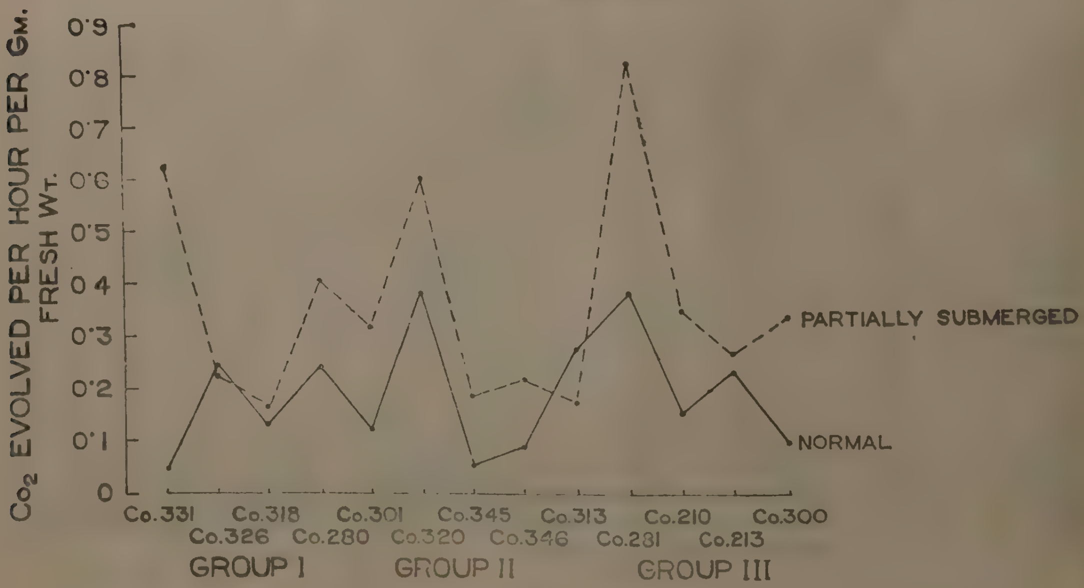

Fig. 3.
Rate of respiration of roots

Co. 281. A regular fall in the respiration curve will be noticed from third to seventh day. Thus according to the similarity of curves of foliage respriation the varieties may be classed as under :

Group I	Co. 285, Co. 326 and Co. 331
Group II	Co. 281 and Co. 313
Group III	Co. 210 and Co. 213

In the case of cane and root respiration, no such regularity in the rate of respiration was observed and, therefore, no such grouping is possible.

The data were statistically analysed. The responses given have been indicated in Table V below.

TABLE V

Statistical analysis of varietal and periodic differences in the respiratory activity of different plant parts (rate of respiration in C.C. per hour per gramme fresh material)

Particulars of material		Varieties		Periods	
		Observed value	Theoretical value P-0·05	Observed value	Theoretical value P-0·05
Foliage	Actuals	4·43*	2·51	0·96	2·51
	Corrected	6·60*	2·51	1·81	2·51
Cane		1·093	2·51	0·025	2·51
Roots		2·38	2·51	1·35	2·51

It will be observed that varieties in their rate of respiration indicated significant differences amongst themselves, indicating that some of the varieties exhibited higher rate of respiration than in others. Differences amongst the mean periodic values, however, were not significant. Cane and root respiration differences were neither significant amongst the varieties nor amongst the periods. It will, however, be noticed that the observed value for significance improved very considerably for the differences in the rate of respiration of the foliage amongst the various periods when corrected values were analysed. This value, however, was not significant at five per cent level of significance but was observed to be significant at 20 per cent level of significance. The data, however, were not sufficient to enable working out interaction between periods and varieties in respect of their rates of respiration, otherwise some confirmatory evidence on the abovementioned grouping would have been evident.

In the following year respiratory studies on the foliage of Co. 213 (Ratoon) and Co. 213 (Plant) crops were undertaken. These crops were growing in the lowland which is the old bed of Tarni Gandak river. Once this lowland is flooded it maintains the same level as the river in spate. The study extended over a period of a fortnight and during the interval, there was a constant rise of river for seven days, when the crop was submerged for a day. Later the water started receding and the fall continued up to the tenth day. The water level was more or less stationary for the next four days.

The data set out in Table VI have been graphed in fig. 2 which indicates more clearly the differences between the rates of respiration of plant and ratoon crops. It will be observed that respiratory activity immediately after partial submergence of the plant crop tended to rise and continued to increase till the fourth day when it rapidly began to drop. It was the least on the seventh day when the crop was almost submerged under water, with the fall in the water level, there was an increased respiratory activity till the day when water again began to rise and a simultaneous decreased rate of respiration was observed. But this rate almost continued to be the same for the next four days.

Rate of respiration of the ratoon crop showed a very abrupt rise within the first 24 hours of partial submergence followed by a continuous fall till the fifth day after which the respiration rate again

began to rise above normal till the seventh day of submergence, when the water had reached its maximum level. After the seventh day though a rise in water level was indicated up to the tenth day and was almost stationary at that level later on, the rate of respiratory activity remained almost at the same level as it was on the tenth day. Unfortunately the data for the depth of partial submergence to which crop was subjected day after day were not recorded, which, it is expected, would have made the study more interesting. All the same the differential response in the rate of respiration of the two varieties is evident. When the water had receded it was noticed that plant crop had been very extensively damaged by floods, while the ratoon crop was standing almost undamaged.

TABLE VI

Respiratory activity of Co. 213 (Plant) and Co. 213 (Ratoon) crop foliage under identical conditions of partial submergence (C.C. Co_2 evolved per hour per gramme dry weight of fresh material.

Days after submergence	Plant Crop	Ratoon crop
Normal	0·1840	0·1478
One day	0·1992	0·2776
Two days	..	0·1998
Three days	0·2799	0·1948
Four days	0·4070	0·1483
Five days	0·2238	0·1282
Six days	0·0994	0·2199
Seven days	0·0612	0·2325
Eight days	..	..
Nine days	0·0914	0·2289
Ten days	0·02230	0·2630
Eleven days	0·1097	0·2600
Twelve days	0·1080	0·2550
Thirteen days	0·1005	0·2500
Fourteen days	0·0983	0·2445

GENERAL CONCLUSIONS

Soon after the cane crop is subjected to partial submergence, the free supply of oxygen to the roots and partially to the foliage, which are submerged, is cut off. Oxygen is absorbed by the roots and other submerged plant parts, as far as it is available, from the water. But if the material possesses normally a high rate of respiration, as that of maize crop leaves, the crop suffers considerably. Clements [1921] has dealt with the effect of the deficiency of oxygen on the growth of roots. Cannon [1917-1919] observed that different species of plants are susceptible in different degrees to low percentage of oxygen in the atmosphere surrounding the plant parts. Bergman [1925, 1930] noticed that injury to plants from scarcity of oxygen was caused due to submergence by flooding. The flowers and tips of the shoots were the parts of the plants most seriously affected by flooding, due to their high respiration rate. The injury to cranberry plants was more pronounced on cloudy than on clear days, because of reduced amount of oxygen released in photosynthesis. In our first experiment the respiratory activity of maize crop suffered more than that of cane and that partly explains greater susceptibility to submergence of the former compared to the latter.

In crop where the foliage of the plants were mostly unsubmerged out of the 11 varieties, except Co. 313 and Co. 320, all others exhibited higher rate of respiration than the normal crop. Similarly cane material, except of varieties Co. 313, Co. 320 and Co. 345, exhibited higher rate of respiration than normal crop. The root respiration, except in varieties Co. 313 and Co. 326, again exhibited higher rate of respiration than unsubmerged material. This difference was noticed amongst the varieties within fifth to eighth day after submergence. Respiration of different plant parts of Co. 313 was lower on the sixth day after submergence than the normal crop. Statistical analysis revealed significant differences in the mean rate of respiration of the normal and submerged material of cane and roots plant organs. The mean rate of respiration of the foliage of submerged crop though higher than the normal, the difference was not significant.

Controlled experiments on the rate of respiration of the foliage, roots and cane parts of the plant indicated that with the elapsing time the different varieties exhibited different modes of respiration day after day. This was evident from a study of the curves of foliage respiration of the seven varieties under experiment (Fig. 1). The first group consisted of varieties Co. 285, Co. 326 and Co. 331. This group is more tolerant to submergence and, therefore, less affected. The second group consisted of those which were susceptible to partial submergence. Evidently in the susceptible ones the reaction, as indicated by their respiratory activity, was very adverse immediately the plants were subjected to partial submergence and the rate of respiration was maintained at a very high level, till it reached its maximum. Beyond that phase, it seems, no further breakdown at that level is possible and the rate of respiration indicated a more steep fall than in the semi-tolerants. The reaction of the tolerant varieties to start with, was the reduced rate of respiratory activity of the foliage. Later on, the foliage regained their functional activity at their original level. Thus in all cases, exigencies of low oxygen supply to roots and other submerged plant parts exhibited some adverse response in the unsubmerged foliage of the cane crop. Different varieties showed distinct variations in this respect.

The trends in the respiration curves of cane and roots plant material are not clearly marked and their interpretation at this stage is not possible. More data on crop actually grown on the land and not on transported material need to be obtained to elucidate the differences amongst the respiratory activity of the varieties.

The conclusions arrived at, from the controlled studies, were observed to be applicable, more or less, to the curves of respiratory activity of Co. 213 plant and ratoon crops when both the crops were subjected to increasing degree of submergence. Both initially showed a rise and then a fall in the rate of respiration. In the ratoon crop this rise was an abrupt one, and of a small degree as compared to the steady rise to a maximum on the fourth day of its partial submergence. The fall in the ratoon crop was much less and for a shorter duration than the plant crop, which maintained a very low rate of respiration from seventh to fourteenth day. In brief, then immediately after submergence it appears that the rate of breakdown of the respirable material quickly increases to a very high rate but is unable to continue at that level and, therefore, a quick fall is recorded and the respiration rate of the plant crop foliage continues at the reduced rate. On the other hand the respiration rate of ratoon crop foliage after a steady decrease is able to meet the environment and keep up its rate of functional activity at a higher rate than the minimum, attained in the experiment. Thus, even with further stress of the adverse environment, the ratoon crop did not suffer much as compared to the plant crop.

Summary

Respiration studies on sugarcane varieties were carried out under conditions of partial submergence. These investigations included (i) a comparative respiration test on maize and cane foliage, (ii) on plant organs of 11 varieties under normal and partially submerged conditions, (iii) controlled experiments on transported plants of Seven Varieties and (iv) experiments on foliage respiration of plant and ratoon crops of Co. 213, the standard variety of the tract. The results of the experiments may be summarized as under:

1. Maize is more susceptible to partial submergence than cane crop, due probably to its high respiratory quotient.

2. After five to eight days of partial submergence to $1\frac{1}{2}$ ft. depth of water foliage, cane and root organs of varieties generally exhibited higher rate of respiration than the normal unsubmerged crop of those very varieties. The differences were statistically significant in the case of cane and roots respiration.

3. Respiration experiments on seven varieties of sugarcane under controlled conditions indicated specific differences in curves of foliage respiration. According to the shape of the curves the varieties studied could be classed as under :

Tolerants	Co. 331, Co. 326 and Co. 285
Semi-tolerants	Co. 281 and Co. 313
Susceptibles	Co. 213 and Co. 210

The tolerant varieties showed an initial slight fall in their respiratory activity which was followed by a steady increase in the rate of respiration that was kept maintained above the normal. In the Semi-tolerants there was a steady decline day by day till the seventh day of the experiments. Lastly, in the susceptible ones there was quick rise in the respiratory activity which was kept maintained up to five days. During the next two days the fall was very slight.

Root and cane organs did not exhibit well marked differences, as have been described above, for the foliage respiration of the varieties.

4. The ratoon crop of Co. 213 was observed to be more tolerant than its plant crop. The course of respiration exhibited was widely different in the two cases.

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WEIGHTED MEAN, POPE'S MEAN AND ARITHMETIC MEAN : A COMPARISON

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One of the methods of determining mean fibre-length of a cotton is to take a large number of fibres from a representative sliver, measure the length of each fibre and then find the Arithmetic mean of all the values obtained. This method is very tedious and takes a lot of time. Therefore, the general practice is to calculate the mean fibre-length, from the weight of different groups of fibres sorted into lengths differing by $\frac{1}{8}$ of an inch with a Balls' Sorter. The calculation of the mean fibre length-weighted mean—is made by the following formula :

$$\text{Mean fibre length} = \frac{1 \varepsilon w l}{8 \varepsilon w}$$

where w denotes the weight of each group and l the mid-value of class length in $\frac{1}{8}$ inch and the summation is taken over all the groups.

Pope [1933] on the other hand calculates the mean fibre length by formula : $\frac{1 \varepsilon w}{8 \varepsilon w/l}$

No attempt has so far been made to compare the values of mean fibre-length, obtained by these two different formulae with each other as well as with the actual Arithmetic mean values. The mean fibre-length results for Standard Indian Cotton obtained by the use of these two different formulae as well as their Arithmetic means are discussed in the following paragraphs.

Discussion of results

The values for mean fibre-length for sixteen standard Indian cottons obtained by using weighted mean formula and Pope's formula are given in Table I.

Table I

Weighted mean, and Pope's Mean for sixteen standard Indian cottons and their fibre-length irregularity and H. S. W. C. S.

Variety	Season	Mean fibre length in.		Difference (W—P) in.	Fibre length irregularity per cent.	H. S. W. C. S.
		Weighted mean (W)	Pope's mean (P)			
Sind N. R.	1937-38	0·72	0·69	0·03	8·7	7's
Mollisoni	1929-30	0·70	0·67	0·03	9·8	8's
P. A. 4 F	1931-32	0·71	0·68	0·03	10·7	20's
V. 434 (Akola)	1936-37	0·85	0·81	0·04	11·8	27's
Late Verum (Nagpur)	1932-33	0·88	0·83	0·05	12·8	31's
Jayawant	1937-38	0·96	0·91	0·05	13·7	39's
Koilpatti	1937-38	0·89	0·84	0·05	14·7	26's
Wagad 8	1935-36	0·77	0·72	0·05	15·9	12's
Umri Bani	1936-37	0·81	0·75	0·06	16·6	30's
Karunganni	1933-34	0·82	0·76	0·06	18·6	25's
Hagari	1941-42	0·92	0·85	0·07	17·9	33's
Cambodia CO2	1936-37	0·92	0·86	0·06	19·7	33's
N 14	1939-40	0·90	0·83	0·07	20·8	42's
1027 A. L. F.	1940-41	0·91	0·84	0·07	21·5	30's
L. S. S.	1940-41	0·77	0·70	0·07	23·2	35's
Sind Sudhar	1941-42	0·90	0·81	0·09	24·4	45's

D

It will be seen that the values obtained for Pope's mean are always lower than those obtained for weighted mean. Hence, only one of these can, if at all, represent the Arithmetic mean. It is necessary to find out which of these is accurately or approximately equal to the Arithmetic mean. For this purpose the theoretical conditions, under which the Arithmetic mean is either equal to the weighted mean or to the Pope's mean, have to be considered. This could be done as follows :

Let $w_1, w_2, w_3 \ldots w_n$ be the weight of respective sections
$l_1, l_2, l_3 \ldots l_n$ be the mid-value of respective class lengths
$N_1, N_2, N_3 \ldots N_n$ be the number of fibres in respective sections
$u_1, u_2, u_3 \ldots u_n$ be the weight of unit fibre in respective sections
and $k_1, k_2, k_3 \ldots k_n$ be the weight per unit length in respective section

then $u_1 = k_1 l_1$; $\quad u_2 = k_2 l_2$; $\ldots\ldots$ & $u_n = k_n l_n$ (i)

$w_1 = N_1 u_1$; $\quad w_2 = N_2 u_2$; $\ldots\ldots$ & $w_n = N_n u_n$ (ii)

$w_1 = N_1 k_1 l_1$; $\quad w_2 = N_2 k_2 l_2$; $\ldots\ldots$ & $w_n = N_n k_n l_n$ (iii)

and $N_1 = \dfrac{w_1}{k_1 l_1}$ $\quad N_2 = \dfrac{w_2}{k_2 l_2} \ldots\ldots$ & $N_n = \dfrac{w_n}{k_n l_n}$ (iv)

(A) Arithmetic mean $= \dfrac{\varepsilon N_1 l_1}{\varepsilon N_1}$

$$= \frac{\varepsilon \dfrac{w_1 \quad l_2}{u_1}}{\varepsilon \dfrac{w_1}{u_1}} \ldots\ldots\ldots\ldots\ldots\ldots \text{from (ii)}$$

If $u_1 = u_2 = u_3 \ldots\ldots = a$ (*i. e.*, if the unit fibre weight is the same for all group lengths).

$$\text{then} \quad \text{A.M.} = \frac{\dfrac{1}{a}\, \varepsilon w_1 l_1}{\dfrac{1}{a} \varepsilon w_1}$$

$$= \frac{\varepsilon w_1 l_1}{\varepsilon w_1} = \text{Weighted mean}$$

(B) Arithmetic mean $= \dfrac{\varepsilon N_1 l_1}{\varepsilon N_1}$

$$= \frac{\varepsilon \dfrac{w_1}{k_1 l_1} \; l_1}{\varepsilon \dfrac{w_1}{k_1 l_1}} \ldots\ldots\ldots \quad \text{from (iv)}$$

If $k_1 = k_2 = k_3 \ldots\ldots = b$ (*i.e.*, if the fibre weight per inch length is the same for all the group lengths)

$$\text{then, A.M.} = \frac{\frac{1}{b}\,\varepsilon w_1}{\frac{1}{b}\varepsilon w_1/l_1} = \frac{\varepsilon w_1}{\cdot\cdot w_1/l_1} = \text{Pope's mean}$$

Thus, it is seen that theoretically, the Arithmetic mean is exactly equal to the weighted mean, if the unit fibre weight (u) is constant for all group lengths ; and it is precisely the same as the Pope's mean if the fibre weight per unit length (k) is constant for all groups. In practice, however, it is found that both u and k vary from group to group in each cotton. It may be said that the Arithmetic mean is nearer the Peope's mean if the variation of k from group to group (v^k) is less than a similar variation exhibited by u from group to group (v_u). A comparison of v_k and v_U would be made from the data available for nine cottons studied by Nanjundayya and Ahmad [1938]. Coefficient of variation calculated for fibre weight per unit fibre and fibre weight per in. in the different group lengths of these cottons is given in Table II.

TABLE II.

Coefficient of variation for fibre weight per Unit fibre and fibre weight per in. of different group lengths

Cotton	Season	Coefficient of variation for fibre weight per unit fibre	Coefficient of variation for fibre weight per in.
		Per cent.	Per cent.
N. 14	1929-30	18·4	8·1
C. A. 9	1929-30	29·4	14·9
1027 A. L. F.	1929-40	29·9	25·8
Jayawant	1929-30	14·4	19·2
Verum 262 (Nagpur)	1929-30	34·2	8·0
Cambodia CO2	1929-30	35·8	10·0
P. A. 289-F	1929-30	28·9	19·7
....	...	...	...
Sea Island	1929-30	37·2	20·8
Sudan Sakel	1929-30	28·5	7·6

It is observed that the latter varies much less than the former which indicates better uniformity in fibre weight per in. from group to group than in fibre weight per unit fibre. As such it can be concluded that Pope's formula based on the uniformity of fibre weight per unit length is better for estimating the Arithmetic mean for a cotton.

It would be interesting to compare weighted mean and Pope's mean with the Arithmetic mean determined experimentally. The Arithmetic mean of a sample could be computed if weight per fibre in each group length is known. The weight of a single fibre in each group could be obtained by taking the fibres from each group and weighing them in a sensitive balance. The data obtained

for Dharwar I [1926-27 season] are given in the Appendix and the detailed calculation is also shown there.

Values of mean fibre-length obtained by both the formulae as well as the Arithmetic means for eighteen standard Indian cottons are given in Table III.

TABLE III

Mean fibre-length values obtained by using Weighted mean and Pope's formulae and their Arithmetic means for eighteen standard Indian cottons

Cotton	Season	Weighted mean (in.)	Pope's mean (in.)	Arithmetic Mean* (in.)
A. 19	1926-27	0·66	0·63	0·64
Mollisoni	1926-27	0·68	0·64	0·65
K. 22	1926-27	0·73	0·69	0·69
H-25	1926-27	0·77	0·74	0·74
4-F.	1926-27	0·78	0·75	0·74
J. N. 1	1926-27	0·78	0·75	0·76
Wagad 8	1926-27	0·80	0·76	0·76
Gadag I	1926-27	0·80	0·76	0·77
Umri Bani	1926-27	0·81	0·77	0·78
285-F	1926-27	0·84	0·77	0·77
C. 7	1926-27	0·85	0·80	0·80
Wagad 4	1926-27	0·86	0·82	0·82
C. A. 9	1926-27	0·87	0·83	0·84
Dharwar I	1926-27	0·88	0·83	0·85
Co. 1	1926-27	0·93	0·88	0·89
N. 14	1926-27	0·94	0·90	0·91
289-F	1926-27	0·97	0·89	0·89
1027 A. L. F.	1926-27	0·97	0·92	0·92
Grand mean		0·829	0·785	0·790

From the above, it is observed that the Pope's mean differs very little from the Arithmetic mean. Hence if the object is to get a value which is closely akin to the Arithmetic mean, it is the Pope's formula that has to be used. There is, however, one great drawback for a universal use of the Pope's mean—the Pope's means are always found to be lower than the estimates of lengths made by the grader. Of the two, it is the weighted mean that agrees better with the graders' values and so it has to be preferred over the Pope's mean for all practical purposes.

*The values for the Arithmetic means were taken from the unpublished data of Technological Laboratory, Matunga and reproduced under the kind permission of the Director.

The correlation coefficients between weighted mean and Pope's mean and Arithmetic mean for eighteen standard Indian cottons are given below in Table IV.

TABLE IV

Correlation coefficients between weighted mean, Pope's mean and Arithmetic mean for eighteen Standard Indian Cottons

	r	n	z	$\frac{1}{\sqrt{n-3}}$
Pope's mean and Weighted mean	+0·9918	18	2·746	0·258
Pope's mean and Arithmetic mean	+0·9964	18	3·161	0·258
Weighted mean and Arithmetic mean	+0·9870	18	2·414	0·258

From the above Table it will be seen that both the Pope's mean and weighted mean are correlated equally well to the Arithmetic mean. Hence, any of these means could be used to grade cottons without any appreciable change in the order of grading.

How far each of these means are associated with the spinning value can now be examined. The correlation coefficients between weighted means and H. S. W. C.s and between Pope's mean and H. S. W. C.s for 57 Standard Indian Cottons given in Technological Reports on Standard Indian Cottons, 1945 were worked out and these are given below in Table V.

TABLE V

Correlation Coefficient between Weighted mean and H. S. W. C.s and between Pope's mean and H. S. W. C.s for 57 Standard Indian Cottons

	r	n	z	$\frac{1}{\sqrt{n-3}}$
Weighted mean and H. S. W. C.s	+0·860	57	1·29	0·136
Pope's mean and H. S. W. C.s	+0·854	57	1·27	0·136
			0·02 n.s.	

From this it is observed that both the weighted mean and Pope's mean are related to an equal degree with the spinning value.

From Table I it is observed that the difference between the values (Weighted mean and Pope's mean) are not only in the same direction, *i.e.*, weighted mean being always higher than Pope's mean, but are also variable. The variation seems to be closely associated with the variability in the fibre length irregularity per cent. [Ahmad and Navkal 1933]. The correlation coefficient between the two was found to be $+0{\cdot}952 \pm 0{\cdot}025$, which is highly significant.

SUMMARY

(1) Significant differences in mean fibre-length values were obtained by use of weighted mean formula and Pope's formula: weighted mean being always higher than Pope's mean.

(2) It has been theoretically shown that the Arithmetic mean agrees with the weighted mean, if it is assumed that the unit fibre weight is the same for all the group-lengths; on the other hand, it agrees with the Pope's mean, if the weight per unit length is the same in all groups.

(3) From the figures given by Nanjundayya and Ahmad, it has been calculated that the fibre weight per inch varies less from group to group in a cotton than the unit fibre weight which shows a greater amount of variation. So, it has been concluded that the Arithmetic mean will agree better with the Pope's mean than with the weighted mean. That this is actually so has been demonstrated by certain figures given for these three types of means.

(4) Weighted mean, Pope's mean and Arithmetic mean are highly correlated to each other; as such any mean can be used for grading of cottons. Where the object is to get a value near to the Arithmetic mean, Pope's formula can be used; otherwise in all other calculations the use of weighted mean formula is recommended since it gives a value in closer agreement with the grader's estimation.

(5) Weighted mean and Pope's mean are highly correlated with H. S. W. C.s.

(6) The difference between weighted mean and Pope's mean is highly correlated with fibre length irregularity.

Acknowledgements

The writer wishes to place on record his deep indebtedness to Dr. Nazir Ahmad, ex-Director, Technological Laboratory, Matunga, for his advice, sustained help and sympathetic interest in the work. To Mr P. D. Gadkari, ex-Cotton Research Botanist, Nanded, he is grateful for many helpful suggestions. The work described was carried out with the financial assistance of the Indian Central Cotton Committee, Bombay.

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APPENDIX

Calculation of Arithmetic mean from percentage distribution of fibres by weight and weight of unit fibre of different group length for Dharwar I [1926-27].

Mean group length (1) ⅛ in.	Percentage distribution (p)	Weight of unit fibre (w) $\times 10^{-6}$ gm.	$m = \frac{p}{w}$
2	0·5	1·39†	0·36
3	1·7	2·09†	0·81
4	3·5	2·79†	1·25
5	7·8	3·48	2·24
6	15·6	3·81	4·09
7	29·2	4·32	6·76
8	28·2	4·62	6·10
9	10·7	5·21	2·05
10	2·5	5·79†	0·43
11	0·3	6·37†	0·05
Total	100·0		24·14

$$\text{Arithmetic mean} = \frac{1}{8}\,\frac{\Sigma\, ml}{\Sigma\, m}$$

$$= 0{\cdot}85''$$

The values marked † have not been obtained experimentally, but they have been calculated on the assumption that fibre weight per in. is the same for this group as for the adjacent group and even if these groups are left out the Arithmetic mean (0·885 in.) is nearer to the Pope's mean (0·877 in.), than to the Weighted mean (0·900 in.).

SUGAR BEET TRIALS IN SIND

By R. T. Mirchandani, Department of Agriculture, Sind, Karachi

(Received on 22 April 1946)
(with one text figure)

The contemplated increase in the *rabi* cultivation under the Lloyd Barrage and Canals Scheme in Sind necessitated research work on the possibilities of cultivating crops other than wheat, during the *rabi* season. In a search for crops supplementary to wheat attention was devoted to the possibilities of cultivating sugar beet (*Beta vulgaris* L.) in Sind.

The cultivation of this crop was first tried on a small scale in the *rabi* season of 1936-37. The growth of the crop was satisfactory and the yields obtained were encouraging. As a result of this, detailed experiments were carried out for two years, 1937-38 and 1938-39.

Introductory

Soil requirements

Sabbahia [1901] reports that in Europe, where the cultivation of sugar beet originated and is practised on an intensive scale, well drained, deep and friable loams are most sought after. Bailey [1922] reports that clay loam has been found to be one of the most satisfactory type of soil. Lill [1930] states that higher and more satisfactory yields are generally secured on the heavier types such as loams, silt loams, clay loams and clays. Nuckols [1931] mentions that heavy clay soils are somewhat better adapted to sugar beet growing. The soil of Sind is alluvial and consists of types ranging from sandy loams to clay loams.

Climatic requirements

Sabbahia [1901] observes that those parts of North India where wheat and potatoes thrive may be taken to possess a climate suitable for the growth of the beet. Bailey [1922] states that an average temperature of 70° F. during the growing season has a marked influence in producing satisfactory sugar content of beet. Lill [1930] reports that 'In addition to the adequate supply of moisture, experience has shown that the sugar beet crop is favoured by a long and moderately cool growing season. All the factories operating in the North Central States are located between the isotherms of 67° and 72° F., mean summer temperature'. Nuckols [1931] reports that 'Sugar beet needs a growing season of at least five months. Areas that have an average temperature of 70° F. for the summer months are generally best adapted for sugar beet'. Similar climatic conditions excepting the rainfall under which sugar beet crop is grown in United States prevail in Sind during the *rabi* season. The mean temperature for the *rabi* season, October to March as recorded at Sakrand, works out to 67·8° F. as the average of five years from 1932 to 1937. The irrigation facilities more than compensate the rainfall which provides adequate moisture in other countries.

Method of cultivation

The land for sugar beet received the necessary preparatory tillage, *i.e.*, two to three ploughings and clod-crushings, and was manured with 20 cart loads (about ten tons) of compost per acre. The seed was dibbled on ridges 2 ft. apart, with a spacing of 9 in. between plants. The seed rate used was 4 to 5 lb. per acre. The thinning of the crop was done when the fourth leaf appeared, *i.e.*, about a month after germination. Weedings and interculturings were carried out when necessary. When the crop was about two months old, earthing up was done. Irrigations were given as per requirement of the crop. In the first month in order to hasten germination the crop was irrigated at very short intervals. During the months of December, January and February, when the temperature was low, the interval of irrigation was 20 to 25 days, and in the month of March when there was a rise in temperature, the interval was shortened. The crop received in all about 30 acre inches by plot delivery. The area was laid out into sub-plots (1/40 acre) and so canalized that each sub-plot

was irrigated direct from the channel. After about five months the developed roots were dug out by *kodar* (hand hoe) and tooped, that is to say the top portion or crown was cut off at right angles, to the long axis of the beet, and at a point indicated by the lowest leaf scar.

Experimental work

In the first year, *i.e.*, 1936-37, a simple experiment with four dates of sowing, viz., 26 October, 2, 9 and 16 November, each at an interval of a week, was laid out with a view to know the best time of sowing the sugar beet crop. The seed of the variety sown was obtained from Messrs. Suttons & Co. October sowing gave significantly higher yields than last two November sowings. The detailed results obtained are shown in Table I.

TABLE I

Average yields of beet roots in the date of sowing experiment

	Sowing dates yield of roots in lb. 26—10	2—11	9—11	16—11	General mean	S. E.	General effect	C. D. in lb.
	A	B	C	D				
Yield per plot	622·5	525·0	488·75	483·75	530·00	33·4	Significant	@p=0·01 133·6
Yield per acre	26,768	22,575	21,016	20,801	22,790	..	..	5,685
Percentage of general mean	117·4	99·0	92·2	91·3	100	6·3	..	25·2

$\overline{A\ B}\ \underline{C\ D}$

The results of preliminary trials were very encouraging. For determining the possibilities of extension of beet crop in the barrage zone in Sind, it was necessary to find out the period during which the regular supply of beets could be maintained for feeding the factories if established, as the economic running of the factories would depend on this. With this object in view in the following two years 1937-38 and 1938-39, a complex experiment combining dates of sowing and harvesting was conducted.

Four sowing dates, *viz.* (1) end-September, (2) mid-October, (3) end-October and (4) mid-November, each at about a fortnight's interval, were tried. Harvesting was carried out at fortnightly intervals from early March to the beginning of May in all the plots. The experiment was laid out according to 'split plot design'. The observations regarding stand, yield of topped roots and sucrose content at different stages were recorded.

(*a*) *Germination and the final stand*—

During both the years it was observed that the germination in the plots sown in the end of September and beginning of October was not uniform and was comparatively less than that in the later sowings, viz., in the end of October and the middle of November. In the first two sowings, some of the young seedlings succumbed due to high temperature which prevailed at that time. In 1938-39 counts of the established plants were taken before harvesting and the results obtained are shown in table II.

It is clear from the above results that the late sowing, viz., mid-November is significantly better than the rest.

(*b*) *Yield of roots*

(i) The yield of roots after topping was recorded on different dates in different sowings. The yields of beets sowing and harvesting dates and interaction were all found significant in the first year and in the second year the yields on harvesting dates and interaction were significant and those dates of sowings were not significant. The summary of the results is given in Tables III and IV.

TABLE II

Stand of the crop in 1938-39

	Mean number of plants in different sowings (Mean of 6 replications)				General Mean	S. E.	General effect	Critical difference @ p = 0·01
	End-September A	Mid-October B	End-October C	Mid-November D				
Stand per plot	220	207	261	352	260	26·02	Significant P= 0·01	76·68
Stand per acre	9,900	9,315	11,745	15,840	11,700	1170·9	..	..
Percentage on general mean	84·6	79·9	100·7	135·9	100	10·0	..	

D>C A B

TABLE III

Summary of results of experiments on dates of sowing

Sowing dates	1937-38	1938-39	Average lb	Average tons
	Yield of topped roots per acre in lb.			
End-September (A)	23,002	27,526	25,264	11·3
Mid-October (B)	23,914	21,591	22,753	10·2
End-October (C)	29,95	21,834	21,414	9·6
Mid-November (D)	14,960	21,830	18,395	8·2
General mean	20,718	23,195	21,956	9·8
S. E. per cent	0·97	6·22	..	..
General effect	Significant @ P = 0·01	Not significant	..	..
C. D. per acre in lb.	735·55	1554·75	..	..
Order of merit	B>A>C>D	A>C D B		

TABLE IV

Summary of results of experiments on dates of harvesting

Harvesting dates	1937-38	1938-39	Mean lb.	Mean tons
	Yield of topped roots per acre in lb.			
(a) Mid-February	8,780	..	8,780	3·9
(b) Mid-March	15,504	17,381	16,442	7·3
(c) End-March	19,406	24,750	22,078	9·9
(d) Mid-April	23,820	23,456	23,638	10·6
(e) End-April	28,341	22,556	25,448	11·4
(f) Mid-May	27,880	28,012	27,946	12·5
General mean	20,630	23,220	21,925	9·8
S. E. per cent	9·36	5·9	..	..
General effect	Significant @ P = 0·01	Significant @ P = 0·01		
C. D. per acre in lb.	5114	..	..	..
Order of merit	e f d c b>a	f c d e>b		

F 2

(c) *Sucrose content*

The sucrose content of the beets was determined on different harvesting dates. The samples of the beet for analytical purposes were taken from all the replications. On each harvesting date samples were drawn from all the replications separately for different sowing dates. From each sub-plot, having stand between 40 to 50 plants, six beets were picked at random and beets from all the replications were mixed. From this lot again, 6 to 7 beets were finally picked up at random and sent to the Agricultural Chemist for analysis. In the laboratory, the beets were cut into bits and representative samples taken for analyses. The fortnightly average sugar content as obtained on different harvesting dates is shown in Table V.

TABLE V

Average sucrose percentage at different harvesting dates

Sowing dates	Harvesting dates				
	Beginning of March	Middle of March	End of March	Middle of April	End of April
End-September	13·88	14·79	14·79	14·64	13·15
Mid-October	13·10	13·88	14·46	15·32	13·99
End-October	12·72	14·17	13·83	14·21	15·65
Mid-November	9·82	12·15	12·42	14·12	14·64

DISCUSSIONS

(a) *Sowing dates*

The observations made by Sanyal [1925] showed that beets of good quality and yield were produced when sown in the months of October and November. It will be seen from Table III that first sowing, viz., the end-September, has given significantly higher yield than the end-October and mid-November sowings. It is also evident that in spite of the low stand in the early sowing, the yield is sufficiently high. The weight of individual beets was quite high and this compensated the low stand.

(b) *Dates of harvesting*

Examining the mean yield of beets in Table IV it will be seen that the yield of beets per acre increased with delay in harvesting period. The yields obtained till the middle of March were significantly lower than those obtained in April and May. The roots harvested in the month of May were unhealthy due to rotting which was the result of rise in temperature and were unfit for any use. The crop therefore could not be left on the ground beyond end of April. For further discussions therefore the last harvesting date has not been taken into consideration.

The mean yield of roots for two years in the different sowings obtained at about fortnightly intervals during the months of March and April are shown in Table VI.

Hutchinson and others [1936] report ten tons per acre as the average yield of sugar beet in the United States. According to Hughes and Herman [1938] the yields of sugar beet in the United States range from 5 to 20 tons per acre with the average of approximately ten tons. Porter [1929] reports an yield of 8 to 12 tons of roots per acre in the United Kingdom. In Bihar, Sanyal [1925] recorded yields varying from 9·34 to 11·74 tons per acre in different sowings; while Sabbahia [1901] in North India obtained yields varying from 16,301 lb. (7·3 tons) to 28,169 lb. (12·6 tons) from different varieties sown in heavily manured plots. Taking ten tons as the minimum yield to start with and examining the yields in Table VI, it is seen that at Sakrand, irrespective of the date of sowing, an yield of ten tons and above is obtained in about 5½ months after sowing and the maximum yield recorded is 12·95 tons per acre.

TABLE VI

Average yield of roots per acre on different harvesting dates

Sowing time	Harvesting dates: Beginning of March (results of one year)	Middle of March	End of March	Middle of April	End of April
	Yield in tons				
End-September	10·7	11·0	11·52	10·6	12·0
Mid-October	7·7	8·13	9·95	11·15	12·95
End-October	5·7	6·3	9·15	11·10	10·10
Mid-November	4·2	5·05	7·55	9·00	10·45

Sucrose content

The results of fortnightly analysis made by Sanyal [1925] showed that, although the sowings were done at different periods, the crop in the various fields matured practically at the same time, *i.e.*, by about the end of February. Sanyal further reports that the quality of the crop could be maintained for a long time. According to him the crop which matured in the middle of February and was allowed to remain till the middle of May did not deteriorate in quality and remained in good condition during all these three months. Examining the sucrose content obtained at Sakrand and shown in Table V, it will be seen that, irespective of the sowing dates, about 14 per cent sucrose is obtained after about five months after sowing and that the maximum sugar content is reached in about six months after sowing. In the first two sowings at Sakrand in both the years it was observed that there was a decline in the sugar content after the maximum was reached. These observations could not be confirmed in the latter two sowings as due to high temperatures in May, the crop could not be left long in the field. The maximum period for which the crop sown in September and October could be left unharvested under Sind conditions was only two months—March and April.

The sugar analysis of several varieties, which were grown in rows in a separate trial and which were sown at the end of October also showed that about 14 per cent sucrose was obtained at the end of March, *i.e.*, after about five months after sowing and that the crop could be kept on until the end of April, after which the roots started rotting on account of high temperature.

The glucose content of the beets was also determined in different sowings along with sucrose and was found to be negligible and it started rising in the tail end of the harvesting period. The maximum quantity recorded was 0·167 per cent in the last harvesting, viz., the end of April harvesting of September-sown crop.

Profitable range of harvesting period

For successful production of sugar beet crop, the yields must be sufficiently high and sucrose content must be adequate to permit profitable manufacture of sugar. To determine the profitable harvesting period, the average yield per acre (Table VI) and the sucrose percentage on different harvesting dates (Table V) have been combined and the total quantity of sugar available per acre has been calculated and shown in Table VII, and the data have been plotted and shown in Fig. I.

The yield and sugar content of beet crop as obtained in England are shown in Table VIII.

Taking 1·4 tons of sugar per acre (10 tons of roots with 14 per cent sucrose) as the minimum standard for determining the profitable harvesting range and examining the curves in Fig. 1, it would be seen that in the September-sowing harvesting can be started from early March, while in the mid-October and end-October sowings, harvestings can commence from the end of March and the beginning of April respectively. In the November-sowing the minimum quantity is obtained in the end of April only. Thus if the sugar beet crop is sown at intervals from the end of September to the end

of October, harvesting can be profitably done from the beginning of March to the end of April, *i.e.*, for two months. The mid-November sowing would be economical only in case the beet crop could be kept on the land after the end of April, but at this period the temperature begins to rise and the beets start rotting. The average yield of roots during this profitable harvesting period of crop sown in September-October works out to 11 tons and the average sucrose content to 14·43 per cent, thus giving an average estimated yield of 1·58 tons (3,539 lb.) of sugar per acre.

TABLE VII

Estimated available sugar per acre in tons

Sowing date	Harvesting dates				
	Beginning of March	Middle of March	End of March	Middle of April	End of April
End-September	1·49	1·62	1·71	1·54	1·5
Mid-October	1·01	1·12	1·44	1·71	1·68
End-October	0·72	0·88	1·30	1·52	1·58
Mid-November	0·41	0·62	0·92	1·11	1·52

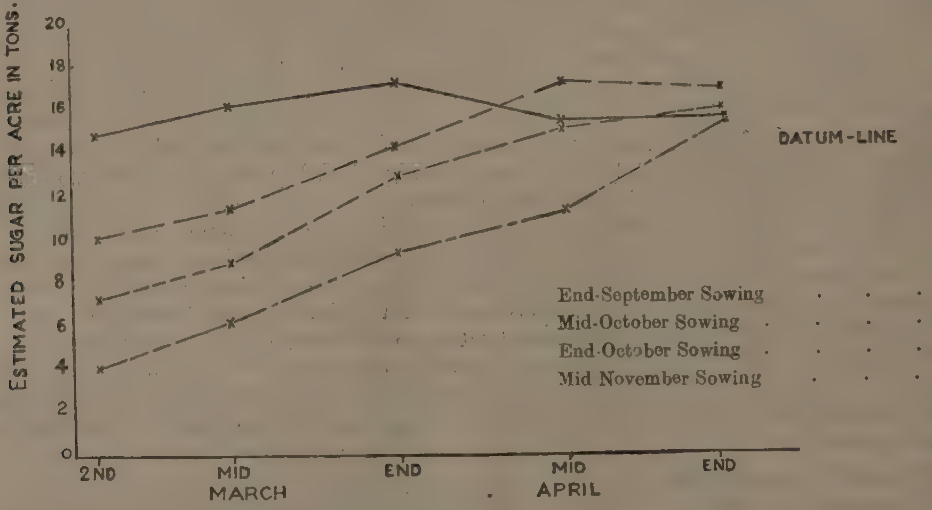

FIG. 1. The total estimated sugar per acre in sugar beet crop.

TABLE VIII*

	1927 Low yielding year	1928 High yielding year	Average
Number of fields	172	167	..
Average yield of washed beets per acre in tons	7·711	9·035	8·373
Average sugar content (expressed in percentage)	16·1	17·9	17·0
Total available sugar per acre in tons	1·24	1·62	1·42

* Bailier's *Encyclopaedia of Scientific Agriculture*, Vol. II, p. 1171.

The average estimated yield of sugar recorded by Lill [1930] in some trials conducted in the humid areas of the United States was 3924 lb. (1·75 tons) per acre. As per Table VII, 1·62 tons of sugar per acre is the yield obtained in Great Britian in a high yielding year. The yields obtained at Sakrand, therefore, compare favourably.

From a commercial point of view the period during which the crop could be kept on the ground after it has matured is not long enough to allow economic working of a sugar beet factory, unless a satisfactory arrangement for storing of beets is made.

Summary

Suitability of sugar beet crop as a *rabi* crop under the soil and climatic conditions preva ling in the Barrage tract of Sind has been discussed. The cultivation method followed has been described. Experiments to determine the optimum period and the profitable harvesting period have also been described. The results indicate that the crop sown in the end of September and during the month of October can be profitably harvested during the months of March and April. During this harvesting period an average yield of 11 tons of roots has been obtained with 14·43 per cent sucrose content. The crop becomes ready for harvest in about $5\frac{1}{2}$ months after sowing and the crop cannot be left unharvested beyond April as the temperature rises in the month of May causing rotting of beets.

Acknowledgements

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Head brown with clypeal region lighter, mouth parts—yellowish, the basal and the first flageller segements light brown, the remaining segemnts darker, pro- and mesonotum yellow, mesepisternum and metapleura brownish, propodeum yellowish-brown, while the remaining portion of the thorax dorsally, after mesosternum, dark brown. Wings hyaline, veins and stigma (with metacarpus) brownish-yellow. Abdomen brownish except the petiole which is yellowish, ovipositor-sheath subconical, greyish-brown in colour.

Type ♀ and 2 paratype ♀♀ (mounted on slide) deposited in the Entomological collection of the Division of Entomology, Indian Agricultural Research Institute, New Delhi. No ♂♂ could be reared.

Type-locality—Harnai (Baluchistan).

Collection 3 ♀♀ reared from *Pterochlorus persicae*, affecting peach trees in the vicinity of Harnai in Baluchistan during the spring of 1937.

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APHIDIUS ANTENNATUS SP. NOV. PARASITIC ON PTEROCHLORUS PERSICAE CHOLODK., AFFECTING PRUNUS PERSICA (PEACH) IN BALUCHISTAN

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(Received for publication on 25 August 1947)

(With one text figure)

Among the family Braconidae, the members of the sub-family Aphidiinae belonging to the Genus *Aphidius* are of special importance, in that they have specificity for parasitizing the different species of the family Aphidae, which are common pests of various crops throughout the world. A systematic study of the species of the Genus *Aphidius* occurring in India, is thus of considerable importance. Unfortunately, very few species have so far been recorded from India. The author has described in the present note, a new species parasitic on *Pterochlorus persicae* Cholodk., affecting peach trees in Baluchistan and has compared it with the only other species recorded from South-India.

Aphidius antennatus sp. nov. differs from *A. pisivorus* Smith., in the antennae of the female, generally being 22 segmented, including scape, whereas, in the *pisivorous* female, they are 19 segmented. The propodeum in *pisivorus* is very dark, ferruginous to black, whereas, in *antennatus*, it is dark brown. In *A. medicaginis* Marshall, an European species, the metacarpus in the female is sub-equal to one-half the length of the stigma, while in the female of *antennatus*, the metacarpus is nearly always as long as the stigma. In the *pisivorus* the second *abscissa* of the radius is two or more times as long as the cross-vein, whereas, in the *antennatus*, the second *abscissa* is sub-equal to the cross-vein, which is distally indistinct and incomplete. In *antennatus* the first *abscissa* of radius is somewhat longer than the second *abscissa*, while the intercubitus is slightly more than half as compared to the first *abscissa*. The new species differ from *Colemani* Viereck., the only other species recorded in India at Bangalore (Mysore) from *Aphis* sp., on tobacco in the size, which in the latter case is 2 mm., in colour it is blackish and in the 14 jointed antennae of the female.

Length 3·5 mm., head—smooth and shiny, width 0·64-0·68 mm., facial line 0·40-0·42 mm., inter-ocular line 0·37-0·39 mm., antenna 22 segmented, pedicel 0·10 mm., first flageller segment 0·068 mm. (somewhat globular), second segment 0·136 mm., rest of the antennal joints similar and sub-equal, the terminal being slightly more than twice as long as broad.

Thorax—smooth, notauli either absent or indistinct, propodeum with fine lateral carinae and areola.

Wing—length of stigma 0·442 mm., metacarpus 0·408 mm., first *abscissa* of radius 0·204 mm., second *abscissa* 0·170 mm., cross-vein 0·136 mm., venation as per text fig. 1.

Fig. 1

Abdomen—smooth, petiole—length 0·374 mm., ovipositor 0·136 mm.

IMPROVEMENT OF THE MANGO, *MANGIFERA INDICA* L. BY SELECTION AND HYBRIDIZATION

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(Received for publication on 12th March 1947)

(With plates I—VI)

WITH the predominently monoembryonic mangoes of India [Hartless, 1914 ; Burns and Prayag, 1921 and Popenoe, 1927], mass selection has been the practice through centuries for extension and perpetuation of superior varieties. Being heterozygous and cross-pollinated, the mango continuously gives rise to innumerable variant offsprings, distinct from the parents for various characters. The propagation of the chance seedlings is rendered possible by the widespread use of inarching as well as by other vegetative methods as budding and side-grafting. Since bud sports have not so far been recorded in mangoes, and are believed to occur only very infrequently, the work of reproduction of the superior chance seedlings or of the hybrid progeny from the controlled pollinations is a matter that presents no difficulties.

This very ease in the reproduction of desirable variants has partly inhibited the study of the hereditary make-up of the Indian mangoes, so that little or no knowledge is available on the inheritance of characters. The selection of parents in a regular breeding project, therefore, is of uncertain value, since the valuable character of a parent may not be reproduced in the seed progeny, while a mediocre variety may, on the other hand, prove superior as a parent. The absence of knowledge of rootstock influence on the cultivated mango is another feature that may also render the mango breeding programme somewhat difficult in view of the fact that the characters of rootstocks are now recognized to be second only to the characters of the variety in determining the successful production of hybird mangoes [Mangness, 1937].

It is not surprising, therefore, that mango literature is characterised by very meagre references to varietal improvement by hybridization. A number of workers have studied the blossom biology and pollination and the results of such studies on some of the South Indian mangoes have already been published [Naik and Rao, 1943]. Burns and Prayag were the first in India to attempt crossing in mangoes [1921]. From 1911-1915 they did a total of 647 crosses, from which only four fruits matured on the trees ; and seeds of only three were planted. The latest available report on these hybrids is to the effect that only one has fruited, but this has not been introduced into cultivation. [Traub and Robinson, 1937]. Mango breeding programmes are also reported to have been initiated in the United States and Puerto Rico [Traub and Robinson, *ibid*], but the practical results from such work are yet awaited, although Sturrock [1944] reports that the Haden X Carabao crosses made by Simonds as well as other crosses between Indian varieties and Philippine varieties by the same worker resulted in promising hybrids, though these remain yet to be given a thorough trial in general plantings.

It seems, therefore, clear that the possibility of originating varieties superior to those under commercial culture at present has not been taken advantage of to any extent in any part of the world. This is surprising in view of the facility with which chance seedlings of superior merit have spontaneously arisen and have been perpetuated in this country as well as elsewhere. The great popularity enjoyed by Haden, which was grown from a seed of Mulgoba in Florida, and its rapid spread throughout the mango-growing regions except India, in spite of its being a capricious bearer, is an instance of what can be achieved by systematic breeding.

When the Fruit Research Scheme was inaugurated at Kodur in 1935, it was therefore felt necessary to include in the programme of that station the work of variety improvement through selection and controlled pollination. After the preliminary work on blossom biology and pollination studies was completed, controlled pollination was commenced actually in 1940. Up to date 7,308 mango flowers have been control-pollinated, employing a large number of parental combinations. From these, only 88 F_1 progenies could be raised from seed. In the 1946 season, six of the above hybrids

produced fruit for the first time. Vegetative and fruit characters of three of these six hybrids have been recorded, and these have disclosed such superior characters as to offer great promise of their future popularity.

Almost equally encouraging results have been achieved from the study of the performance of chance seedlings mostly from known parents. Of the 42 seed progenies of known monoembryonic parents planted in 1939, 25 seedling trees have yielded fruit crops by 1946. From the descriptions recorded, six progenies are found to be sufficiently promising to be of practical interest to the mango producers.

With the hope that the foregoing results would be of both scientific and practical interest to a large class of those engaged in mango production as well as to many among the innumerable lovers of the mango fruit in this country and elsewhere, the following descriptions of the superior chance seedlings and hybrids are presented.

From the point of view of fruit quality , the three superior hybrid progenies are ranked below in the order in which they are described.

1. F_1 *Progeny* 7/5. This is a cross between the choice-fruiting but shy-bearing Himayuddin staminate and the prolific and regular-bearing Neelum female parents. The seed was sown on the date 9th September 1941 and the first crop was harvested from 10th June 1946 to 29th July 1946. The yield in 1946 was 70 fruits, as against the year's average of 55 fruits per tree of Himayuddin on the station on grafts on about nine years of age.

The fruit (Plate I, fig. 1 and Plate IV, fig. 1) is medium to large, oval, weighing 12 oz. ; 4·8 in. long, 3·3 in. major diameter ; 2·9 in. minor diameter ; base rounded with a slight extension at the stalk end ; stalk inserted squarely ; cavity absent ; shoulders equal and level, ventral shoulder rounded, dorsal shoulder ending in a long curve ; apex rounded ; beak slightly prominent to mammiform ; sinus slight to shallow ; dots medium and close ; skin medium thick, leathery, cadmium yellow (L. 7. Plate 9)* flesh firm, fibreless, apricot yellow (L. 4. Plate 9)* ; juice moderately abundant ; flavour delightful ; taste very sweet.

Stone oblong, covered with short, soft fibre all over ; veins forked and slightly depressed.

Fruit quality very good ; bearing in mid-to-late season ; keeping quality good.

Tree medium, top rounded, shoots medium thick. Leaves outheld, oval lanceolate, slightly reflexed and folded with sub-acuminate tip.

The progeny resembles Himayuddin in respect of beak, form of the fruit and quality of flesh, and Neelum in respect of vegetative characters of tree and leaf.

2. F_1 *Progeny* 9/3. This is also a cross between the choice-fruiting and shy-bearing Himayuddin staminate and prolific and regular-bearing Neelum female parents. The seed was sown on 16th December 1940 and the first crop was harvested from 19th June 1946 to 17th July 1946. The yield in 1946 was 17 fruits only, as against the year's average of 55 fruits per tree of Himayuddin on the station on grafts of about nine years of age.

The fruit (Plate I, fig. 2) is small to medium, ovate oblique, weighing 5 oz., 3·0 in. long, 2·6 in. major diameter, 2·6 in. minor diameter ; base obliquely flattended to rounded ; stalk inserted squarely ; cavity absent ; shoulders equal, ventral higher than dorsal, ventral shoulder rising and then rounded, dorsal shoulder ending in a long curve ; apex rounded ; beak a point ; sinus slight ; dots medium ; close ; skin smooth, medium-thick, leathery, primuline yellow (L. 5. Plate 9) ; flesh firm, fibreless, mustard yellow (F. 3. Plate 39) ; juice scant ; flavour delightful ; taste very sweet.

Stone oblong oval, covered with short, sparse fibre all over ; veins forked and prominently raised.

Fruit quality very good ; bearing in mid-to-late season ; keeping quality medium to good.

Tree medium, top rounded, shoots medium thick ; leaves outheld, oval lanceolate, slightly reflexed and folded with acute tip.

The progeny resembles Neelum in respect of shape of the fruit and vegetative characters, and Himayuddin in respect of quality of flesh.

* Such figures in parenthesis relate to the colour standards of Mearz and Paul [1930], while the colour descriptions preceding the figures relate to the standards of Ridgeway [1912].

FIG. 1
H 7/5

FIG. 2
H 9/3

FIG. 3
Ko 16

The fruit (Plate III, fig. 2) is medium, ovate ; weighing $7\frac{1}{2}$ oz.; 3·5 in. long, 2·7 in. major diameter, 2·4 in. minor diameter ; base rounded ; stalk inserted squarely ; cavity absent ; shoulders equal and level, ventral shoulder rounded, dorsal shoulder ending in a moderate curve ; apex rounded ; beak slightly mammiform ; sinus shallow ; dots small and close ; skin smooth, medium-thick, leathery, cadmium yellow (L. 8. Plate 10) ; flesh soft, fibreless, moderately juicy, primuline yellow (L. 7. plate 9) ; flavour pleasant ; taste sweet.

Stone broadly oval, covered with dense, short, soft fibre all over ; veins parallel and grooved.

Fruit quality good ; bearing in mid-season ; keeping quality medium.

Tree medium, top rounded and shoots slender. Leaves out-held, slightly reflexed, oval lanceolate, flat, slightly wavy with sub-acuminate tip.

The fruit resembles Dilpasand in respect of fruit characters and Mulgoa (also known as Mulgoba) in respect of vegetative characters.

6. *Seedling Progeny K. O. No. 16.* This is a seedling progeny of Hamlet. The seed was sown on 10th July 1939 and the first crop was harvested from 19th May 1944 to 23rd June 1944. The yield in 1946 was 90 fruits as against the year's average of six fruits only per tree of Hamlet on the station on grafts of about nine years age. In 1944 and 1945 the tree yielded 31 and 73 fruits respectively.

The fruit (Plate III, fig. 3) is small, ovate oblique to oblong oblique, weighing $2\frac{1}{2}$ oz. ; 2·7 in. long, 1·8 in. major diameter, 1·6 in. minor diameter ; base slightly obliquely rounded ; stalk inserted squarely ; cavity absent ; shoulders equal, ventral slightly higher than dorsal, ventral shoulder slightly rising and then rounded, dorsal shoulder ending in a long curve ; apex rounded ; beak absent ; sinus slight ; dots small, close ; skin smooth, medium-thick ; leathery, primuline yellow (L. 6. Plate 9) ; flesh firm, primuline yellow (L. 6. Plate 10) ; moderately juicy, slightly fibrous, fibres short and soft ; flavour pleasant ; taste sweet.

Stone oblong, covered with short, coarse fibre all over ; veins forked and slightly raised.

Fruit quality good ; bearing in mid-season ; keeping quality medium to good.

Tree medium to large, top oval, shoots medium thick. Leaves outheld, moderately reflexed, oval lanceolate, slightly folded and crinkled with acuminate tip.

The variety resembles Alphonso in fruit and vegetative characters.

In recording the above descriptions, comparison has been made between some of the progenies and the parental varieties in respect of fruit quality. Owing to limitations of space the descriptions of the latter are not presented here but they will be found in *The Monograph on Classification and Nomenclature of South Indian Mangoes* by K. C. Naik and S. R. Gangolly, which is now in press.

It would be clear that among the chance seedlings, K. O. 11 and K. O. 22 are likely to strike the fancy of the mango producers, since both of these are characterised by superior fruit quality and high-yielding tendencies. The remaining four progenies are of a quality which cannot be deemed as outstanding.

Importance of polyembryony

Juliano [1936] has referred to the impracticability of using polyembryonic varieties as female parents in breeding of the mango, basing his inference on the supposed difficulties or impossibility of distinguishing macroscopically the sexual embryos from the adventitious embryos and the fact that vigour is not a safe guide to decide which of the seedlings is the sexual. Yet, Sturrock [1944] has reported that crosses between the monoembryonic Indian varieties and the polyembryonic Philippine varieties have been made at Miami with satisfactory results. He also refers to the report that Mulgoba (syn. Mulgoa) which is monoembryonic in India, reverted to poly embryony in its first generation when grown in Florida.

Work at Kodur on the crossing between the polyembryonic and monoembryonic mangoes afford sufficient evidence to dispel the fears expressed by Juliano [1936] on one hand, and to explain the

alleged reversion of the monoembryonic mangoes to polyembryonic, on the other. In Table I are set out the details of crosses made between the two groups and of the behaviour of the progenies.

TABLE I

Details of crosses between polyembryonic and monoembryonic mangoes with the nature of progenies

S. No.	Female pasent	Male pasents	Number of stones in each cross.	Number of seedings secured from each stone.
1	Neelum=monoembryonic	Muvandan=polyembryonic	1	3
2	Kurukkan=polyembryonic	Neelum=monoembryonic	1	3
3	Goa=polyembryonic	Jehangir=monoembryonic	1	4
4	Ditto	Ditto	1	4
5	Ditto	Ditto	1	3
6	*M. zeylanica*=polyembryonic	Rumani=monoembryonic	1	2

It is evident from Table I that regardless of the fact whether the polyembryonic variety is a male or female parent the hybrid progeny is polyembryonic. This justifies the conclusion that the reported reversion of Mulgoa (syn. Mulgoba) to polyembryony in Florida must have been due to the contamination from pollen of the polyembryonic trees. It has been suggested that the results of crossing monoembryonic and polyembryonic mangoes may in effect be a distinct case of metaxenia, pollen of polyembryonic mangoes affecting the nucellus. Without further observations and investigations, it seems, however, premature to draw definite inferences on this point from the foregoing data.

In view of the small number of seedlings arising from each stone, there does not appear to be any justification for the fear expressed by Juliano [1936] in the matter of using the polyembryonic parents in any mango breeding project. At Kodur, the seedlings from each stone were graded according to size and allotted separate number before planting out in the progeny test plot. As soon as each of these seedlings attains the fruiting age, the distinguishing of the sexual seedlings from the nucellar ones is found easy in practice, although such a distinction cannot possibly be made with ease in the pre-bearing stage. The value of a hybrid progeny cannot in any case be appraised till after it has fruited, and therefore there could be no possible objection to the delay in distinguishing of the nucellar seedling from the sexual, till that stage.

SUMMARY

1. Descriptions of three hybrid progenies and six chance seedlings of good fruit quality are given.

2. Two hybrid progenies and the same number of chance seedlings have been selected as the best from the view-point of fruit quality and high-yielding tendencies for perpetuation as clonal strains.

3. Contamination from pollen of polyembryonic mango tree or the use of a polyembryonic female parent in controlled polination are shown to result in the production of nucellar seedlings in the seed progeny.

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was mainly responsible for recording the descriptions of the hybrids and chance seedlings. The author desires to record the above facts with gratitude.

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WATER-SOLUBLE SILICATES IN AGRICULTURE*

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SILICATES, until recently, were used from the view-point of plant nutrition, in the form of insoluble calcium or magnesium silicates, or colloidal silica. Silicon (one of the constituents of silicates), however, is not considered to be one of the elements essential for plant growth, although this element forms about 28 per cent of the earth's crust.

Laws and Page of Ohio observed in the laboratory that the treatment of certain soils with water-soluble sodium silicate and its subsequent drying made the individual, loose soil particles stick together in large clumps that resisted disintegration when shaken in water. Their research was carried out from the view-point of stabilizing soil materials for the construction of highways.

The experiment done by the author with water-soluble potassium silicate, in order to study its effect on soil structure and crop growth, is the first of its kind ever reported. In case the use of sodium silicate may supply sodium concentrated enough to be toxic to the growth of crops (since sodium is not considered an essential element for plant growth), potassium silicate was used in this experiment. The commercial potassium silicate in solution was diluted with water and sprinkled over the surface of the soil. The moist soil was then turned under to 3 in. depth and the remaining solution sprinkled over the newly exposed surface. Clay, sand and cinders were other treatments and these materials were incorporated thoroughly with the same depth of soil.

Before the application of the above treatments, the entire land was limed and fertilized equally and to such an extent that none of the common nutrient elements, such as nitrogen, phosphorus and potash, would be limiting for the growth of crops. The amount of potash applied for the silicate plots was the same as for other treatments.

For the same treatments, Sudan grass was planted on some plots while the remaining plots were left fallow. The silicate plots gave the highest yield of Sudan grass. The dry-matter yield of Sudan grass per acre was 3085-3279 lb. for the silicate plots, 2492-2692 lb. for cinders, 2154-2688 lb. for clay, and 1978-1997 lb. for sand.

Certain singular features of the soil and growing Sudan grass plants due to the silicate treatment are worth-mentioning. In the second week, it was found that the young Sudan grass seedlings on silicate plots were taller and more vigorous in growth than those on the plots of the other treatments. Moreover, the soil crumbs, originally produced by disking and harrowing prior to the application of these treatments, had slaked down under the beating action of the falling rain-drops and formed a crust on the surface in all the treatments except the silicate. The silicate-treated plots, either fallow or seeded, had still maintained almost to the same degree the initial crumb structure against the disruptive action of rain.

Potassium silicate plots maintained these differences from the time of seeding to that of harvesting of Sudan grass. The Sudan grass on the silicate plots had maintained its growth more than on the plots of other treatments. The crumb structure also persisted in the silicate plots. The boring of holes on the soil surface showed that the soil beneath the surface in the silicate plots was loose and friable while that beneath the surface in the plots of other treatments was hard and compact. Such loose and friable soil comprising a crumb structure, which is the dream of the practical farmers all over the world, will facilitate soil aeration, water absorption and retention by the soil, and at the same time check washing of the soil by rain (soil erosion).

The mere incorporation of organic matter cannot produce and maintain such a crumb structure, as was done by silicate, against the disruptive action of rain, especially in the fallow plots. It can,

* This article has been written with a portion of the materials of the research works done by the author for his Doctorate Thesis at Cornell. The author acknowledges his gratitude to Dr Bradfield, Head of the Dept. of Soils and Agronomy, and Dr M. B. Russel, Prof of Soil Physics (the Chairman and Co-Chairman respectively of his special committee) for their help and guidance in his work.

however, be produced by growing grasses and legumes for two or three years. but such a structure, once ploughed and left fallow, may not possibly maintain itself against the destructive action of rain as well as the one built by silicate can. Furthermore, the time period needed for improving soil structure with water-soluble silicates is much less than it is with grass and legumes. Once the silicate solution has been sprinkled over the surface, it is just a matter of few days for the soil to dry out and obtain a crumb structure.

The American fertilizer industry has recently turned its attention to the manufacture of a product in the form of glass of controlled solubility that will incorporate all the common plant nutrients except nitrogen. The present high cost of potassium silicate may prohibit its use on a large scale. Sodium silicate, which is less expensive, can be tried on the soils of humid regions where there is very little chance for sodium to accumulate and thus give rise to undesirable soil structure as may occur in the dry regions of India. However, more work needs to be done to explore the full agronomic possibilities of water-soluble silicates in agriculture.

DOES SOIL CRUST AFFECT PLANT GROWTH*

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SOIL crust consists of a hard coherent layer of very small soil particles formed on the surface. It is like a layer of cream that appears on the surface of milk when it is allowed to cool after boiling. Such a crust is impervious to air and water and inhibits the growth of crops by limiting the oxygen and water supply for the plant roots and soil organisms. It also limits the nitrogen supply for the microorganisms that fix atmospheric nitrogen in a form available to the plants.

In an experiment done by the author at the Cornell University Experiment Station, a hard coherent crust was artificially formed by puddling with water 0-½ in. of the surface soil and allowing it to dry out. Following this operation, rye and vetch (a legume) were planted in rows by hand, disturbing the surface soil as little as possible. A similar planting of rye alone, and rye plus vetch, was done on soils not puddled. The dry-matter yield of rye and vetch on puddled soil was 4241 lb. per acre while that on non-puddled soils was about 7429-7732 lb. per acre.

The effect of these different treatments on the growth of one-month-old rye and vetch was quite interesting. The plants growing on non-puddled soils were comparatively tall, green and healthy, while those on the puddled soil were of stunted growth and showed marked yellowing of the leaves suggestive of nitrogen deficiency.

Such a crust can also be formed under natural conditions. A soil that contains low amount of organic matter and is liable to become sticky on treatment with water, readily slakes into pieces by the beating action of falling rain-drops just as quick as lime does when it is brought in contact with water. As a consequence, the very small soil particles are brought into suspension which, on drying, forms a hard coherent crust on the surface. It can also be formed following irrigation of such a soil or by plowing it after a heavy rain before it is dry and friable, and so on.

The above experiment was continued after harvesting rye and vetch. The entire land was limed and fertilized to an extent that none of the common plant nutrients, such as nitrogen, phosphorus and potash, would be limiting for the growth of crops. After this, the oven-dry residues of rye and vetch were finely chopped and returned to the respective plots as surface mulch. Sudan grass was then planted. The Sudan grass yielded as much on the puddled plots as on the non-puddled ones, the average yield being a little more than 2 tons per acre. Thus the fact that the actively decomposing organic matter can undo the detrimental effect of puddling on plant growth, is a conclusion that is hard to avoid.

Experiments at Rothamstead (England), north-western Ohio (United States) and elsewhere have shown that soils, even if generously fertilized, cannot produce and maintain high yields when crops, which need frequent cultivation operation, are grown year after year. Such cultural operation hastens the décomposition of organic matter and renders the soil particles susceptible to slaking by rain, leading ultimately to the formation of a hard coherent crust on the surface.

The crops which need such cultivation operation are cotton, corn, potatoes, etc. However, the formation of surface crust can be prevented by the application of organic matter or the like as surface mulch, or by the occasional incorporation of active organic matter that will readily decompose in the soil.

It is, indeed, true that the crying need of our soils almost all over India is for chemical fertilizers, nevertheless, the negligence of the agronomists to the occasional addition of organic matter to the soils will but sabotage the maximum efficiency of chemical fertilizers in increasing our food

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production. This simple practice—that is, the application of organic matter in the form of green manure, farmyard manure, etc.—is often beyond the economic reach of our farmers under the present economic and land tenure systems, although such a practice is as important as chemical fertilizers in producing maximum crop yield.

Unless the agronomists can devise some inexpensive and time-saving practice that will replace organic matter and reproduce at the same time its beneficial effect, organic matter will remain the great hope of the farmers in building up a soil structure that will resist the disruptive action of rain and facilitate the percolation and retention of water by the soil as well as adequate soil aeration. However, the water-soluble silicates offer certain possibilities in this direction and the results obtained by the author are reported in the next article.

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